Thermal Analysis data exchange in the Space Industry

Eric Lebègue, Simulog – France
Georg Siebes, NASA / JPL – USA
Hans Peter De Koning, ESA / ESTEC – The Netherlands

1. Introduction

The engineering of spacecraft and other space-related equipment requires extensive computer-aided design, analysis and test work - this goes for all disciplines and certainly also for thermal control engineering. In most space projects, several organizations work together, often located at different, geographically dispersed sites and they typically use different CAx tools and computer platforms to support their engineering. In order to make the engineering process more efficient and more effective - which is best expressed in the well known "faster, better, cheaper" slogan - reliable, tool-independent, electronic exchange of case, model and results data is highly needed. Ideally, one would go as far as having a shared database which holds the complete electronic product definition as it develops during the product life cycle, shared between disciplines and between project partners.

The classic way of using many point-to-point converters that support the great number of tool-specific data formats does generally not deliver stable solutions. The proliferation of formats and corresponding converter tools place a great burden on software development and maintenance resources. The converter tools need to be regularly updated as data formats change or get extended on either side of an interface. The quality of the converters is often questionable and conversions often result in a considerable loss of information. Finding, implementing and maintaining a high quality mapping of concepts between two tool-specific data formats is a non-trivial task, and for a single point-to-point converter it is often very hard to justify adequate funding and development time.

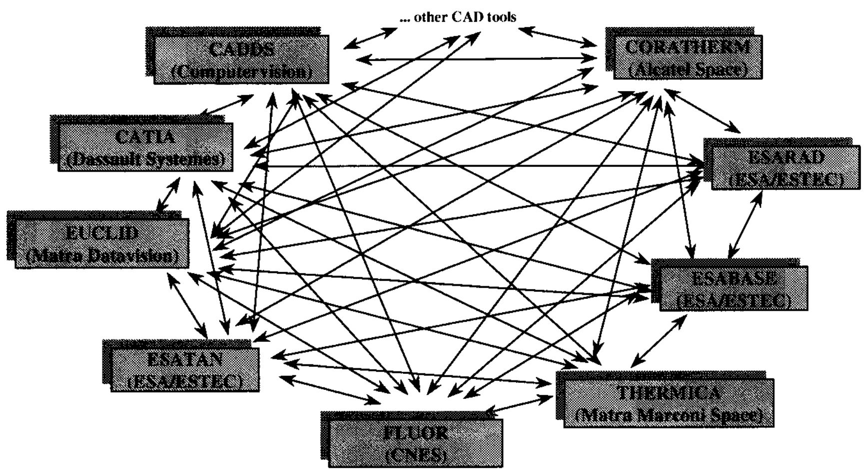

Figure 1 : Yesterday's situation in space thermal analysis data exchange

In the European space industry, after initial implementations and proof of concept using the SET (Standard d'Echange et de Transfert – French AFNOR norm), ESA and CNES decided to use the international standard STEP (ISO-10303).

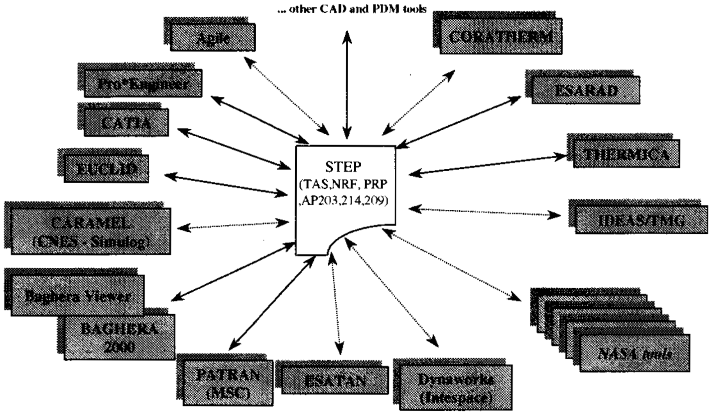

Figure 2 : In progress and future engineering technical data exchange in the European space industry using STEP.

Using STEP, all converter development efforts are concentrated on a single neutral format. It is also possible to connect to main CAD systems which now provide good STEP AP203 interfaces. So the choice of ESA and CNES was to adopt standard STEP protocols, like AP203 for CAD and AP209 for structural analysis, and to develop extensions of these protocols for more space specific needs like thermal analysis (STEP-TAS), generic analysis or tests results of network based model (STEP-NRF), fluid propulsion network and others.

2. The STEP Application Protocols Network for the Space Industry

Among the list of ISO-10303 STEP standard or compliant protocols, some are especially suitable for the space industry. The following figure presents a possible network for these protocols :

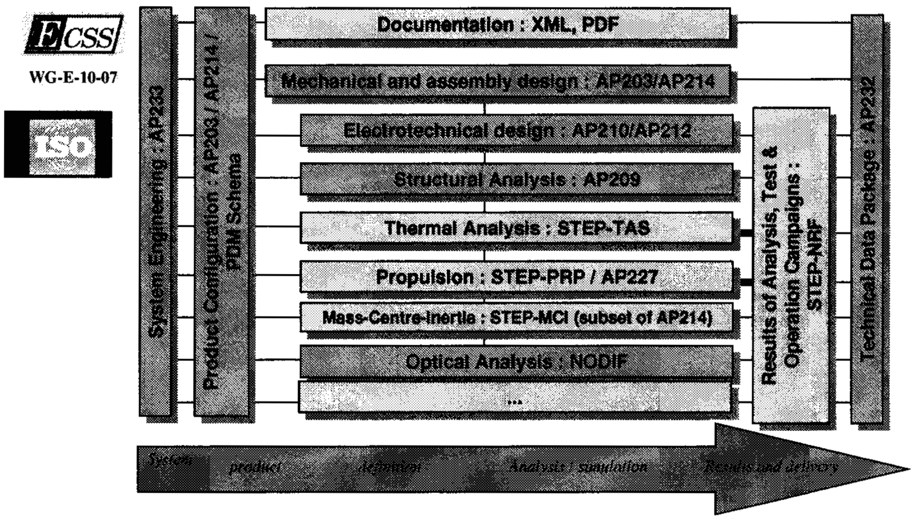

Figure 3 : The STEP Application Protocols network for space

This network presentation means that some protocols can be used for defining file formats for definition data (e.g. AP203 for CAD, STEP-TAS for thermal analysis), while others can be used for defining the structure of shared databases in which some definition data could be stored as attached files (e.g. AP232 for technical data package).

STEP-TAS and STEP-NRF are scheduled to be adopted, by the end of this year, as ECSS (European Co-operation for Space Standardization) standards.

3. STEP-TAS : Thermal Analysis for Space

STEP-TAS is a protocol for the definitions of space missions and models used in thermal analysis.

The space missions part comprises definitions of orbit, space thermal environment, material property environment and kinematic articulation. The model definition comprises surface geometry (including boolean constructive surface geometry), thermal-radiative properties and meshing, kinematic structure, materials and physical properties. STEP-TAS is a pure extension of STEP-NRF. It adds - or tailors - the specific constructs that are needed for space thermal analysis applications.

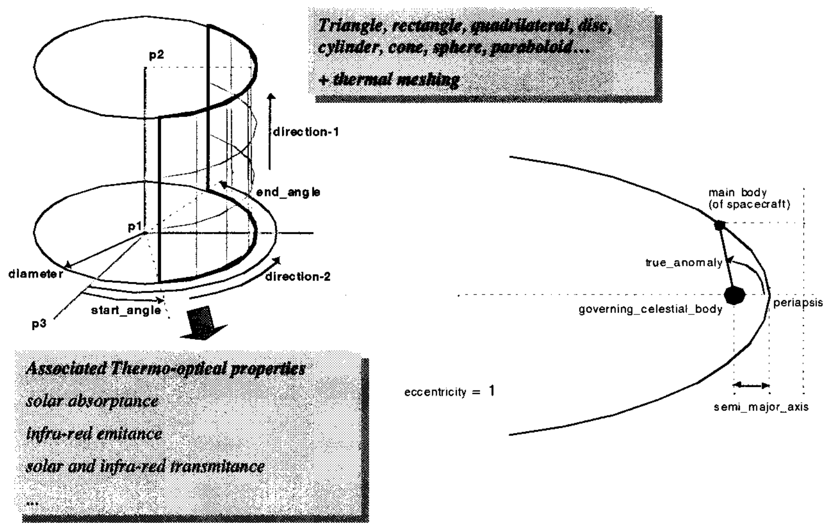

Figure 4 : Simple geometry, meshing, thermo-optical properties and orbits definitions in STEP-TAS.

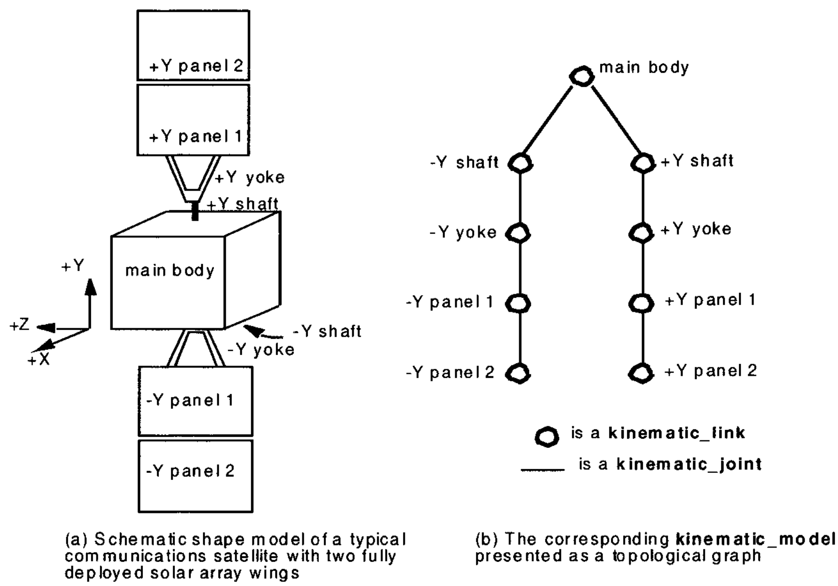

Figure 5 : Product structure and kinematics structure in STEP-TAS.

This protocol is developed by the STEP-TAS Consortium composed of ESA, CNES, SIMULOG, Fokker Space, Association GOSET and ALSTOM.

STEP-TAS is implemented in ESARAD and THERMICA.

See : http://www.espri-concept.com/step-tas

4. The STEP methodology

For developing a new cooperative system, STEP defines a complete methodology, which associates end-users, standard specialists and software engineers.

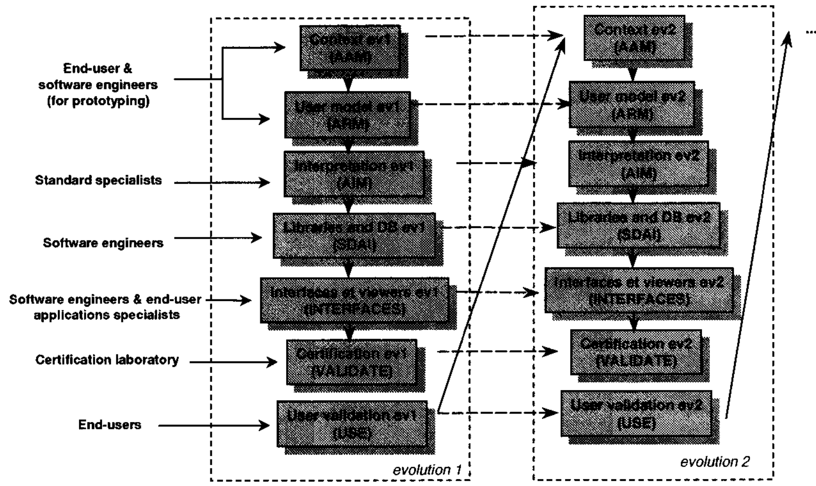

Figure 6 : The STEP methodology cycles for developing co-operation systems.

The output of the two first stages of this methodology is the Application Reference data Model (ARM) which captures the specific needs of end-users, in their own structure and terminology. This model can be defined in EXPRESS (formal language for communicating information concerning data) and can be an output by an OMT/UML case tool. This ARM is interpreted by STEP specialists who produce an Application Interpreted Model (AIM), which is the standard point of view of the ARM, built by importation of existing integrated resources (ISO-10303-41 ... 199) and by definition of new resources connected to the existing ones.

5. High level libraries

However, while standard STEP toolkits provide some mechanism for reading and writing STEP instances, development of standard STEP converters remains difficult for end-user application software specialists, not familiarized with STEP integrated resources.

That is why SIMULOG has developed the concept of STEP High Level programming libraries.

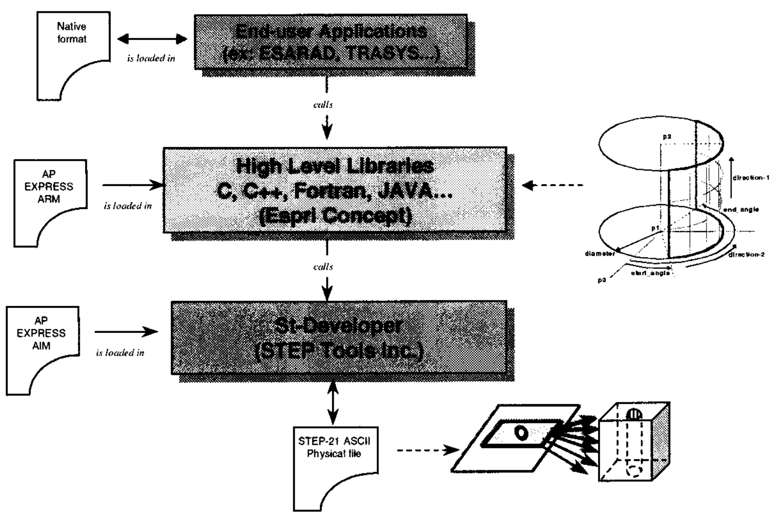

Figure 7 : High level libraries

With these libraries, end-user application software developers access the STEP standard instances via a high level API. Entry points of this API correspond to the ARM objects. So these entry points are easy to understand for end-user applications specialists because they correspond to the objects they have defined themselves.

Then, the high level libraries can be distributed for the connection of applications to the co-operation system.

For the development of these libraries, which is part of the SDAI stage of the methodology, SIMULOG is associated with STEP Tools Inc. which provides the low-level SDAI toolkit for reading and writing standard STEP instances corresponding to the AIM model. High level library source code includes the mapping between ARM and AIM and can be developed using the EXPRESS-X language.

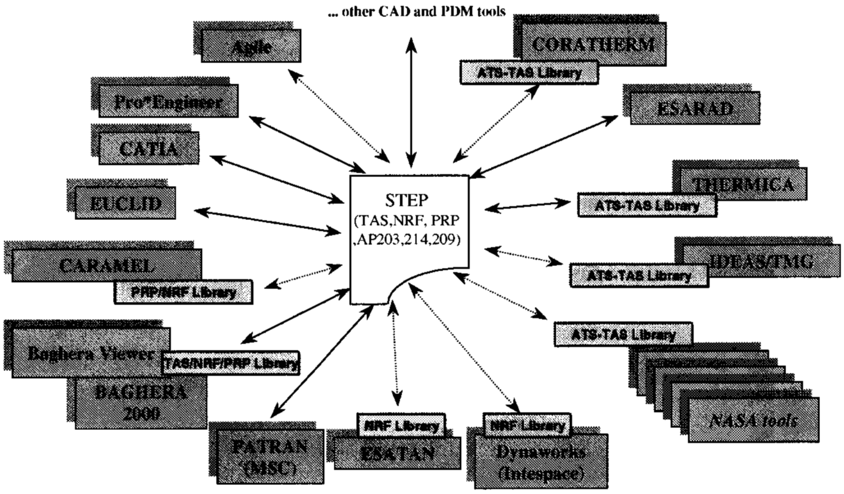

Figure 8 : Distribution of STEP-TAS High Level libraries to ESA and CNES partners for thermal analysis data exchange.

With this concept of libraries, all converters share the same source code for accessing STEP data. This result in very good reliability of the exchange and a gain of time and costs in converter development.

6. Baghera View for visualising STEP space protocols

In order to further improve the reliability of STEP converters, SIMULOG and its partners, CNES, STEP Tools Inc. and TGS, develop the Baghera View software, which permits to display the STEP geometry and associated properties.

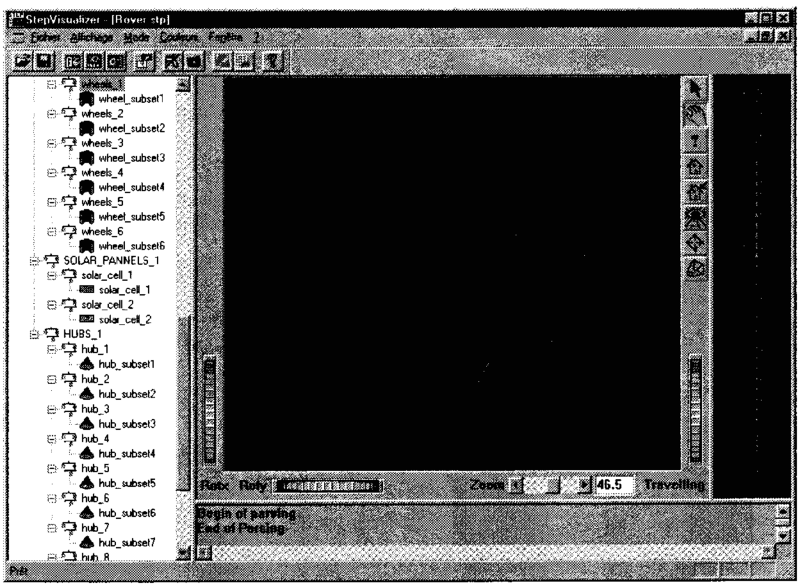

Figure 9 : After being exported into STEP-TAS, from TSS, the Mars Pathfinder thermal model is checked with BAGHERA View (CNES).

These viewers can be used at the converter development stage for checking geometry and the associated property transfers, and after development for displaying engineering data stored into a data warehouse in STEP format.

7. STEP-TAS Industrial implementations

STEP-TAS is now industrially implemented in two European analysis tools, ESARAD (ESA/ESTEC) and THERMICA (Matra Marconi Space) and an implementation is planned for CORATHERM (Alcatel Space). On the American side, two pilot implementations have been performed with NASA on TSS and TRASYS and five more commercial pilots are starting with have Cullimore and Ring Inc. (Thermal Desktop), Harvard Thermal Inc. (TAS), Network Analysis Inc. (SINDA/ATM), SpaceDesign (TSS), and TAC Inc. (NEVADA).

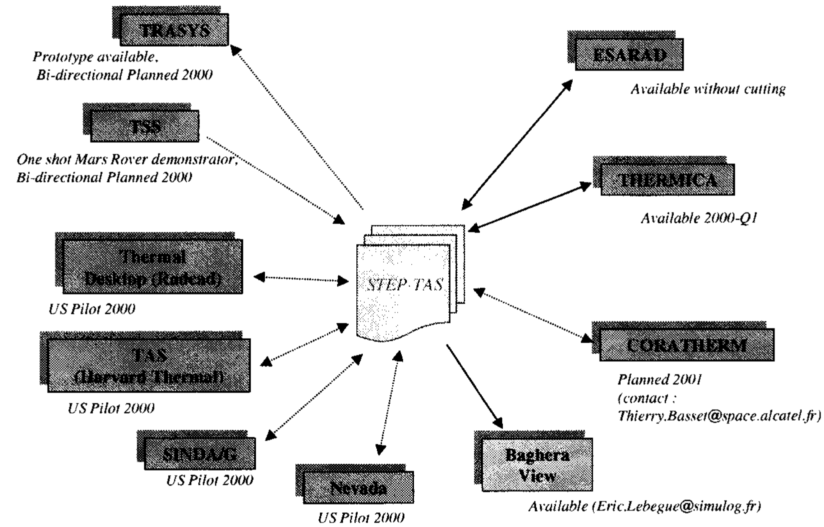

Figure 10 : The current STEP-TAS implementation map

8. European implementation in ESARAD and THERMICA

In Europe, the two first industrial implementation of STEP-TAS are ESARAD from ESA/ESTEC and THERMICA from Matra Marconi Space.

The scope of these bi-directional converters is thermal radiative geometry and assemblies and associated thermo-optical properties which correspond to the conformance class 1 of the protocol.

For these converters, a cross-validation campaign on large models is starting.

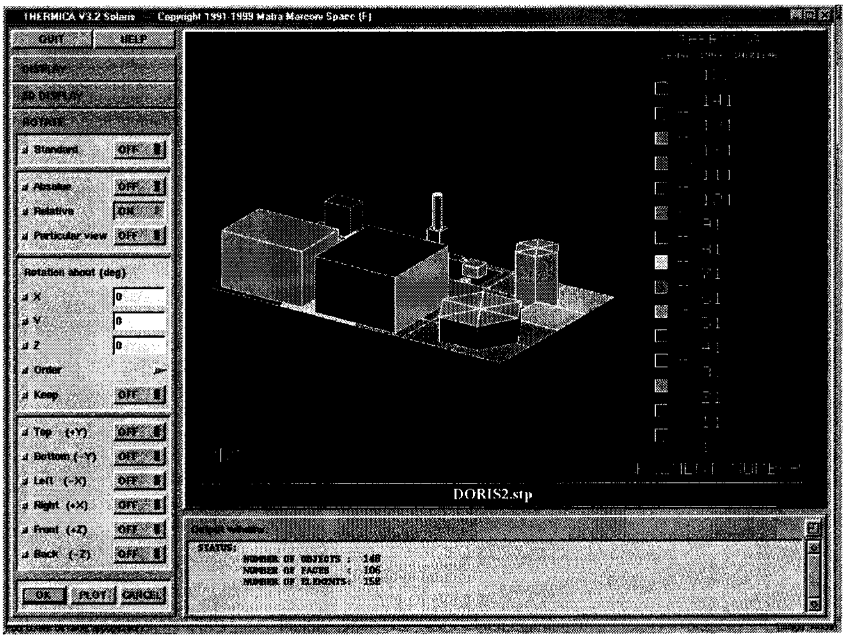

Figure 11 : Thermal radiative model in THERMICA (Matra Marconi Space)

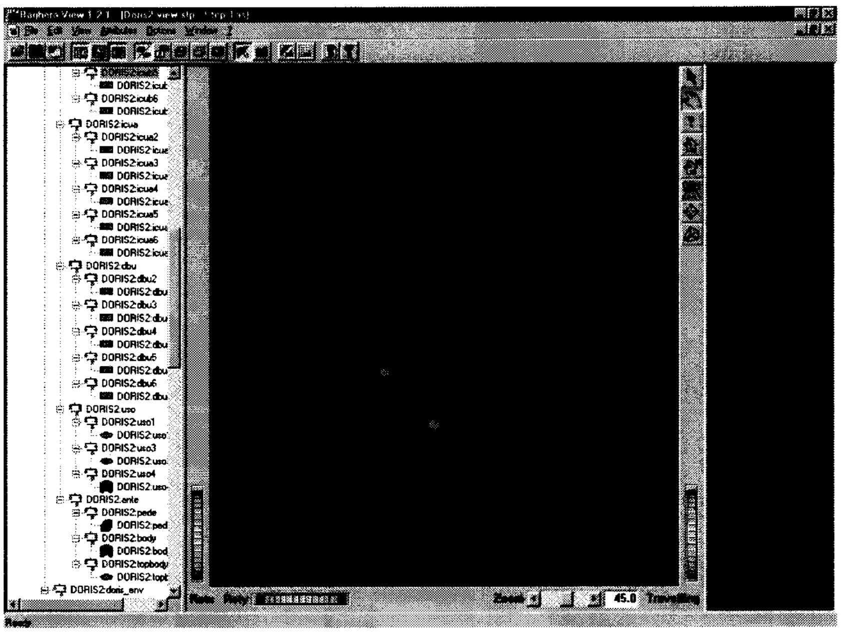

Figure 12 : The same thermal radiative model exported in STEP-TAS and checked with BAGHERA View (CNES)

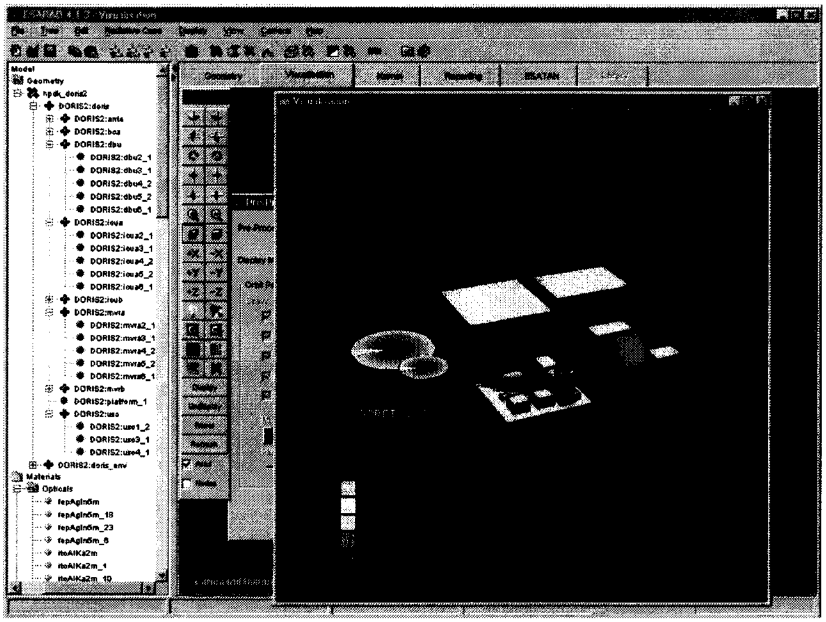

Figure 13 : The thermal radiative model imported into ESARAD (ESA/ESTEC)

9. US STEP-TAS Pilot

This year's STEP for Aerospace Workshop at JPL brought together representatives from the standards developer, tool vendor and user community. It served as the catalyst for further STEP implementation activities in NASA. The most mature of these activities is the STEP-TAS pilot. Five US thermal tool vendors are participating. In alphabetical order we have Cullimore and Ring Inc. (Thermal Desktop), Harvard Thermal Inc. (TAS), Network Analysis Inc. (SINDA/ATM), SpaceDesign (TSS), and TAC Inc. (NEVADA). The scope of this pilot activity is limited by the available funding. However, the objectives require a substantial step towards a complete STEP-TAS implementation in these tools and could not be met without additional contributions of resources from the tool vendors.

Scope

The scope of this effort is limited to the development of a prototype bi-directional STEP-TAS interface of defined and limited capability. The word prototype is used in the sense of a feasibility demonstration. This specifically means that the final product is not required to support all activities that are typically found in a radiation model. The prototype is limited to the bi-directional exchange of the surface geometry and thermal properties based on the following definition:

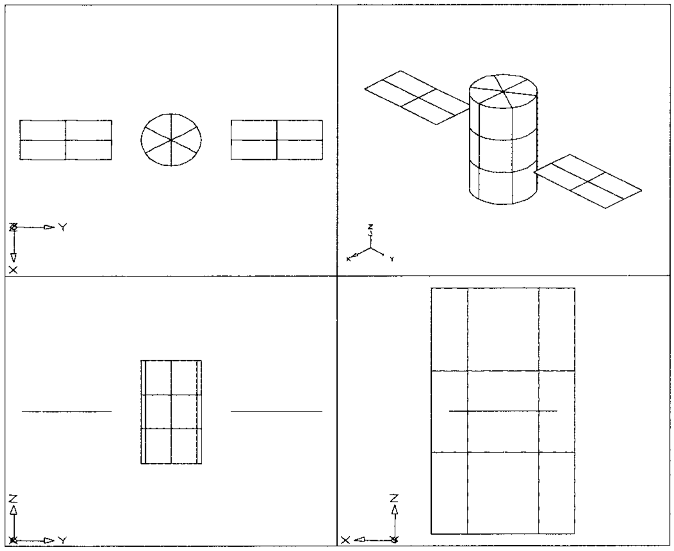

Figure 14 : The US STEP-TAS pilot test model

Objectives

1. Develop a STEP-TAS prototype interface based on the SIMULOG/ESA APIs.

- This prototype can either be embedded into the respective radiation analysis tool or a stand-alone product.
- The prototype shall be bi-directional (tool to STEP-TAS, STEP-TAS to tool).

2. Demonstrate a visual comparison of the native and STEP-TAS based geometry. For the STEP-TAS geometry visualization, apply the visualization tools developed by ESA.

3. The Prototype interface shall be capable of successful bi-directional exchange of the defined geometry. "Successful" is defined as a bi-directional exchange from an analysis tool into STEP and back from STEP into the tool without loss of information. The metric used shall be a defined set of radiation exchange factors calculated before and after the exchange.

4. Once all prototypes have been developed, STEP-TAS models from all developers will be collected and made available to all developers. An attempt shall be made to read and visualize all STEP-TAS files received.

10. Conclusion

Like most industries, the space industry can realize substantial benefits from using STEP (ISO-10303) for exchanging technical data between partners. Geometrical data exchange using the STEP AP203 application protocol are now available and accurate between most CAD systems (CATIA, Pro*Engineer, Autocad...).

Based on the success of this protocol, some new ones are under development which can fit the needs of other space engineering disciplines, like structural (AP209) or thermal analysis (STEP-TAS), electromechanical definition (AP212) or product configuration (AP232).

In the thermal analysis domain, the two European software programs, ESARAD from ESA and THERMICA from Matra Marconi, now have a STEP-TAS interface, although STEP-TAS has not yet completed the process of becoming an international standard. The feasibility study with NASA/JPL is proving that interfacing NASA thermal tools to this protocol requires only a moderate amount of work.

Step opens the door to very effective cooperation between space industry partners and now is the time to speed up its implementation.

11. Acknowledgments

STEP-NRF and STEP-TAS protocols as well as ESARAD / STEP-TAS converter were developed under contract from ESA with support from CNES . The TRASYS and TSS / STEP-TAS converter prototypes were developed by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. Baghera View was developed under CNES contract. The THERMICA / STEP-TAS converter is developed under Matra Marconi Space contract

Phillips

We want to acknowledge the valuable contributions of our co-workers: Charles Philipps of Jet Propulsion Laboratory (JPL) of NASA (USA), Alain Fagot, Sandrine Fagot, Alain Calvaire, Alexandre Minard and Nicolas Soudet of SIMULOG (France), Hans Peter De Koning previously of Fokker Space (The Netherlands), Jean-Luc Le Gal and Christian Puillet of CNES (France), Pascal Huau and Dominique Molin of Association GOSET (France), François Liard and David Flett of Alstom (UK), Jean-Philippe Goube of Intespace (France), Dr Martin Hardwick and Dr David Loffredo of STEP Tools Inc. (USA).

And a special acknowledgement to Pau Planas Almazan who has now left ESA for NTE of Spain and has been instrumental in his push to get things rolling and to keep it rolling.

12. Contacts

Eric Lebègue is the deputy technical manager of Simulog, a French services software company. He is a member of the French delegation to ISO/TC 184 / SC4 committee for STEP project development and also a member of the ECSS committee for product data standardization inside the European space industry.
Eric Lebègue has been charged by ESA, in 1998, to lead the project STEP-TAS&NRF.
E-mail : Eric.Lebegue@simulog.fr
Url : http://www.simulog.fr/

Georg Siebes is the Supervisor of JPL's Thermal and Fluids Systems Engineering Group. He is also a member of the US delegation to the ISO/TC 184 / SC4 committee for STEP project development.
E-mail: georg.siebes@jpl.nasa.gov
URL: http://sec353.jpl.nasa.gov/3536/

Hans Peter De Koning – ESA/ESTEC
D/TOS-MCV
E-mail : hanspeter@yc.estec.esa.nl
URL : http://labs.esa.int

13. References

H.P. de Koning & P. Planas Almazan,
Solutions for the Exchange of Models and Results of Analysis and Tests in the Space Domain - STEP-TAS and STEP-NRF,
SAE Technical Paper Series No. 972448, 27th International Conference on Environmental Systems, Lake Tahoe, Nevada, July 14-17, 1997

H.P. de Koning,
Experiences with the Use of STEP-Based Data Exchange to Enable Concurrent Engineering,
SAE Technical Paper Series No. 972449, 27th International Conference on Environmental Systems, Lake Tahoe, Nevada, July 14-17, 1997

14. For the STEP application protocols, see the "THE STEP APPLICATION PROTOCOLS NETWORK FOR THE SPACE INDUSTRY" paragraph.